

Addendum to Quality Assurance Project Plan for 301(h)  
Waiver and NPDES Permit Renewal Application  
Supplement for Asplund Water Pollution Control Facility

# **Outfall Mixing Zone Study Plan Asplund Water Pollution Control Facility**

Prepared for

**Anchorage Water and Wastewater Utility  
City of Anchorage, Alaska**

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**Jacobs**

## Asplund Water Pollution Control Facility Outfall Mixing Zone Study Plan

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## Acronyms and Abbreviations

AKS	AKS Engineering
AWWU	Anchorage Water and Wastewater Utility
AWPCF	Asplund Water Pollution Control Facility
CID	Critical initial dilution
CTD	conductivity, temperature, and depth
CORMIX	CORMIX modeling software
DEC	Alaska Department of Environmental Conservation
DGPS	differential global positioning system
GIS	geographic information system
HDPE	high-density polyethylene
Jacobs	Jacobs Engineering Group
KEI	Kinnetic Environmental Inc.
mgd	million gallons per day
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
ppb	parts per billion
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
VP	Visual Plumes modeling software
ZID	zone of initial dilution



# 1. Introduction

This Study Plan presents the specific approach for conducting an Outfall Mixing Zone Study of the City of Anchorage's Asplund Water Pollution Control Facility (AWPCF) Outfall 001 in Cook Inlet. This Study Plan includes the project background information, a detailed study approach, methodology for field measurements and dilution modeling, quality assurance and quality control methods, and the plan for reporting. This Outfall Mixing Zone Study Plan has been prepared as an Addendum to the *Quality Assurance Project Plan for 301(h) Waiver and NPDES Permit Renewal Application Supplement for Asplund Water Pollution Control Facility* (Jacobs and Kinnetic Environmental, August 2022).

## 1.1 Project Background

The Anchorage Water and Wastewater Utility (AWWU) operates the John M. Asplund Water Pollution Control Facility (AWPCF). The AWPCF discharges treated and disinfected effluent via Outfall 001 into the marine waters of Cook Inlet offshore off Point Woronzof. The AWPCF Outfall consists of an 84-inch buried pipe that extends approximately 800 feet north from the chlorination tower at Point Woronzof and terminates with a vertical turret with three, 23-inch discharge ports open on the north side of the turret (Figures 1 and 2).

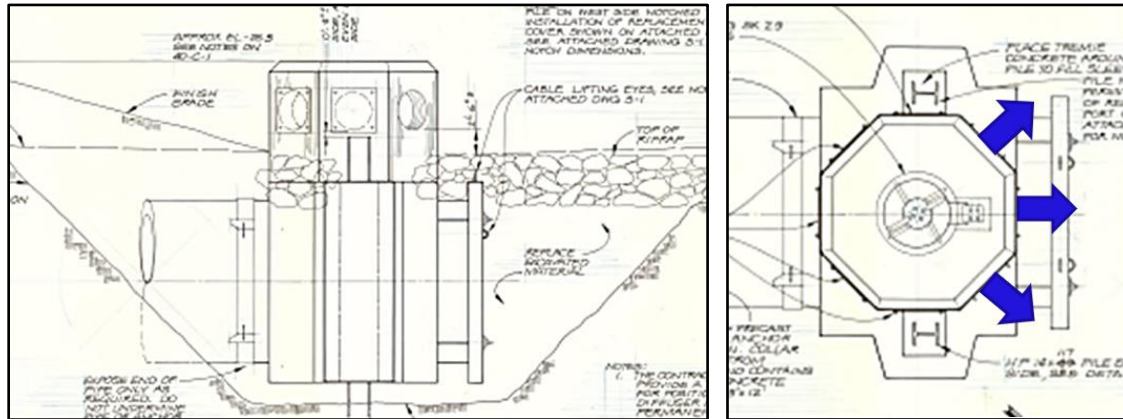


Figure 1. Drawings Excerpts of the AWPCF 84-inch Outfall with Multi-port Turret Diffuser with 3 Open 23-inch Ports

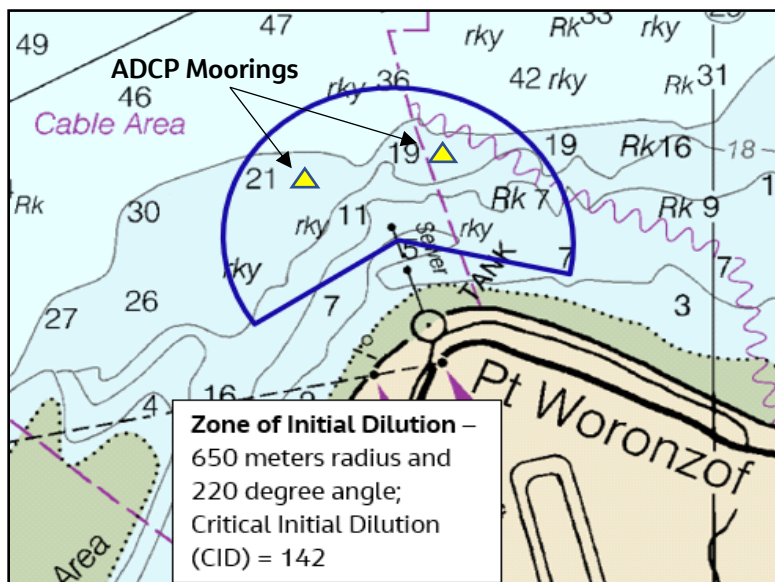


Figure 2. Locations of the AWPCF Outfall at Point Woronzof and Approximate Locations of ADCP Current Meter Installations in Cook Inlet (Excerpt from NOAA Chart 16665)

The Municipality of Anchorage Water and Wastewater Utility (AWWU) is working to develop information for the U.S. Environmental Protection Agency (EPA) to use in the renewal of its NPDES permit and 301(h) variance to discharge primary-treated wastewater from the AWPCF. EPA has indicated that much of the information included in the 2005 application for renewal of the AWPCF NPDES permit and §301(h) waiver is dated and more current information is needed for its review and processing of the permit application. A key element of the 301(h) waiver and NPDES permit renewal is the definition of the Zone of Initial Dilution (ZID) and the associated Critical Initial Dilution (CID). The existing ZID is 650 meters from the AWPCF outfall, and the CID is 142 (Figure 2). The existing ZID and CID were developed through dilution modeling and a field dye tracer study in 1988. EPA has stated that a new field tracer study is needed to support the dilution model selection, validation, and calibration to yield updated dilutions for the AWPCF outfall to use in the 301(h) waiver and NPDES permit renewal applications.

This Outfall Mixing Zone Study will include detailed field data collections to document the AWPCF outfall dilution performance, dilution modeling of the outfall under critical conditions, and a technical mixing zone study report to document the ZID and CID for use in the 301(h) waiver and NPDES permit renewal applications.

## **1.2 Discharge Site Characteristics**

The AWPCF discharges into Knik Arm of Cook Inlet approximately 800 feet north of Point Woronzof (Figure 1). This summary of discharge site characteristics is based on the 2005 301(h) Waiver and NPDES Permit Renewal Application for the AWPCF. The semidiurnal mixed tides in Knik Arm have a diurnal range of 30 feet and an extreme range of 39 feet. These large tidal elevation changes produce strong currents with high ebb and flood current velocities (up to approximately 240 cm/sec; 8 ft/sec) and vigorous mixing off Point Woronzof. Upper Cook Inlet and Knik Arm have mobile sand bedforms, as well as regions of cobble and rocks and extensive intertidal mudflats.

Currents in the vicinity of Point Woronzof are influenced primarily by the tides, freshwater inflow, and geographic features. Figures 3 and 4 illustrate the generalized current patterns in lower Knik Arm in the vicinity of Point Woronzof during ebb and flood tides. These general patterns have been developed based on years of field measurements of current transport near the outfall, including drogue tracking during annual receiving water monitoring for the Asplund WPCF NPDES Permit. Ambient currents in the vicinity of the Point Woronzof outfall diffuser vary in speed depending on the tidal stage. The current velocity measurements (from all sources) are summarized as follows: 46 cm/sec is the lowest 10<sup>th</sup> percentile velocity, 136 cm/sec is the 50<sup>th</sup> percentile velocity, and 195 cm/sec is the 90<sup>th</sup> percentile velocity. Table 1 summarizes the available current measurement data collections near Point Woronzof since 1965.

As part of AWWU's 2022 data collection for the 301(h) Waiver and NPDES Permit Renewal Application Supplement for the Asplund Water Pollution Control Facility, current measurements will be recorded for a minimum of a 15-day period to capture the range of minimum and maximum current velocities associated with neap and spring tidal cycles. Currents will be measured at two locations near the AWPCF outfall using bottom-mounted acoustic Doppler current profilers (ADCPs). Each ADCP will be programmed to measure 1- to 2-meter vertical bins extending from near-bottom above the ADCP instrument to the water surface. Current speed and direction measurements will be made at 6-minute intervals to coincide with the water level measurements from the National Oceanic Survey water level gauge located at the Port of Anchorage to correlate measured currents with water levels.

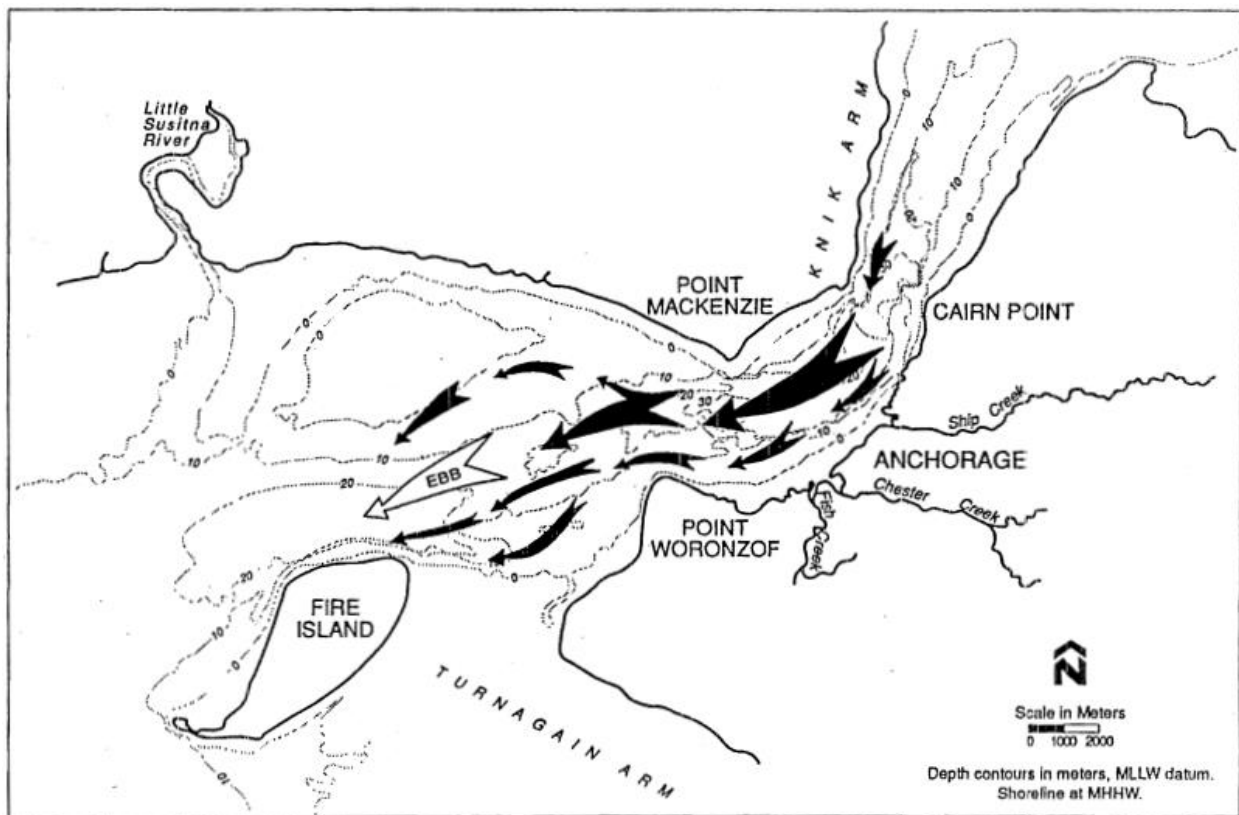


Figure 3. Generalized Current Patterns near Point Woronzof during Ebb Tide

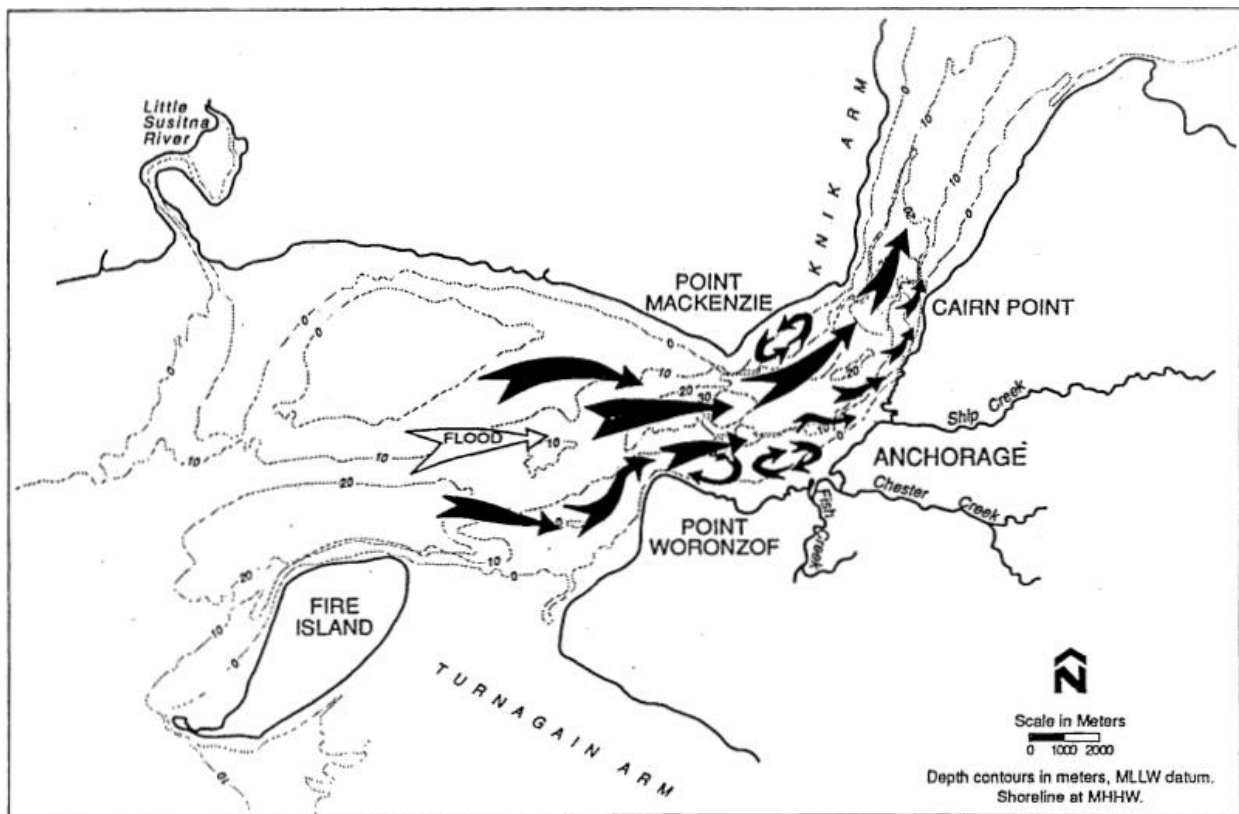


Figure 4. Generalized Current Patterns near Point Woronzof during Flood Tide

Table 1. Summary of Current Measurements Recorded in the Vicinity of Point Woronzof (1965 to 2003)

Year	Month	Date	Current Measurements	Program or Study	Source
1965	August	6-7	Current Meters	Oceanographic study	Marine Advisors
1969	May	21-28	Off Vessel	Oceanographic study	Kinney, et al. (Univ. of AK)
1972	June-Sept.		Current Meters	Currents study	Britch, 1976 (Univ. of AK)
1975			Current Meters	Circulation study	Patchen, et al. (NOAA) 1981
1976	July	21	Current Meters	Shoaling rates	Everts and Moore
1976	August	2,7,10,11,14,17,18,29	Current Meters	Shoaling rates	Everts and Moore
1976	September	5,12,15	Current Meters	Shoaling rates	Everts and Moore
1977	July	26-29	Drogues	Water quality study	Tetra Tech
1977	August	28	Drogues	Water quality study	Tetra Tech
1979	August	14-20	Current Meters	Supplemental studies for Waiver Application	Kinnetic Laboratories
1983	February	6	Drogues	Outfall studies	CH2M HILL
1983	September	23-28	Current Meters	Outfall studies	CH2M HILL
1983	October	1-5	Drogues	Outfall studies	CH2M HILL
1986	May	13-14	Drogues	Annual monitoring program	Kinnetic Laboratories
1986	May	22-23	Drogues	Annual monitoring program	Kinnetic Laboratories
1986	August	3-5	Drogues	Annual monitoring program	Kinnetic Laboratories
1986	October	1-4	Drogues	Annual monitoring program	Kinnetic Laboratories
1987	August	8-9	Drogues	Annual monitoring program	Kinnetic Laboratories
1988	August	1-11	Drogues	Annual monitoring program	Kinnetic Laboratories
1989	May	23-24	Drogues	Annual monitoring program	Kinnetic Laboratories
1989	August	12-13	Drogues	Annual monitoring program	Kinnetic Laboratories
1989	September	27-28	Drogues	Annual monitoring program	Kinnetic Laboratories
1990	August	8-9	Drogues	Annual monitoring program	Kinnetic Laboratories
1991	August	7-8	Drogues	Annual monitoring program	Kinnetic Laboratories
1992	August	12-13	Drogues	Annual monitoring program	Kinnetic Laboratories
1993	August	4-5	Drogues	Annual monitoring program	Kinnetic Laboratories
1994	August	15-16	Drogues	Annual monitoring program	Kinnetic Laboratories
1995	August	8-9	Drogues	Annual monitoring program	Kinnetic Laboratories
1996	August	6-7	Drogues	Annual monitoring program	Kinnetic Laboratories
1997	August	5-6	Drogues	Annual monitoring program	Kinnetic Laboratories
1998	August	11-12	Drogues	Annual monitoring program	Kinnetic Laboratories
1999	August	24-25	Drogues	Annual monitoring program	Kinnetic Laboratories
2000	August	14-16	Drogues	Annual monitoring program	Kinnetic Laboratories
2001	June	19-20	Drogues	Annual monitoring program	Kinnetic Laboratories
2002	July	23-24	Drogues	Annual monitoring program	Kinnetic Laboratories
2003	June	24-25	Drogues	Annual monitoring program	Kinnetic Laboratories

Flushing time in Knik Arm (time required for the volume of water in Knik Arm to be replaced) is a function of tidal excursion (net distance a particle moves each tidal cycle) and advective flow (riverine input). Tidal excursion calculations show a net excursion of approximately 3 miles southwest (ebb), with a flood excursion of 19-20 miles and an ebb excursion of 22.5-23.2 miles.

The major rivers and streams contributing fresh water to Knik Arm include the Matanuska River, Knik River, Eagle River, Ship Creek, and Chester Creek. These sources of fresh water, combined with other rivers flowing into Cook Inlet, keep the salinity of Knik Arm generally below 21 parts per thousand (ppt). Measured water column salinities in Knik Arm show a range from 4 to 13 ppt during the summer and early fall to 16 to 21 ppt in spring (refer to Figure 5), and ice flows occur from November through April. Water column density profiles (based on salinity and temperature data) show no water column stratification (Figure 6) due to the strong tidal-driven currents and vertical mixing in Knik Arm and the Point Woronzof area.

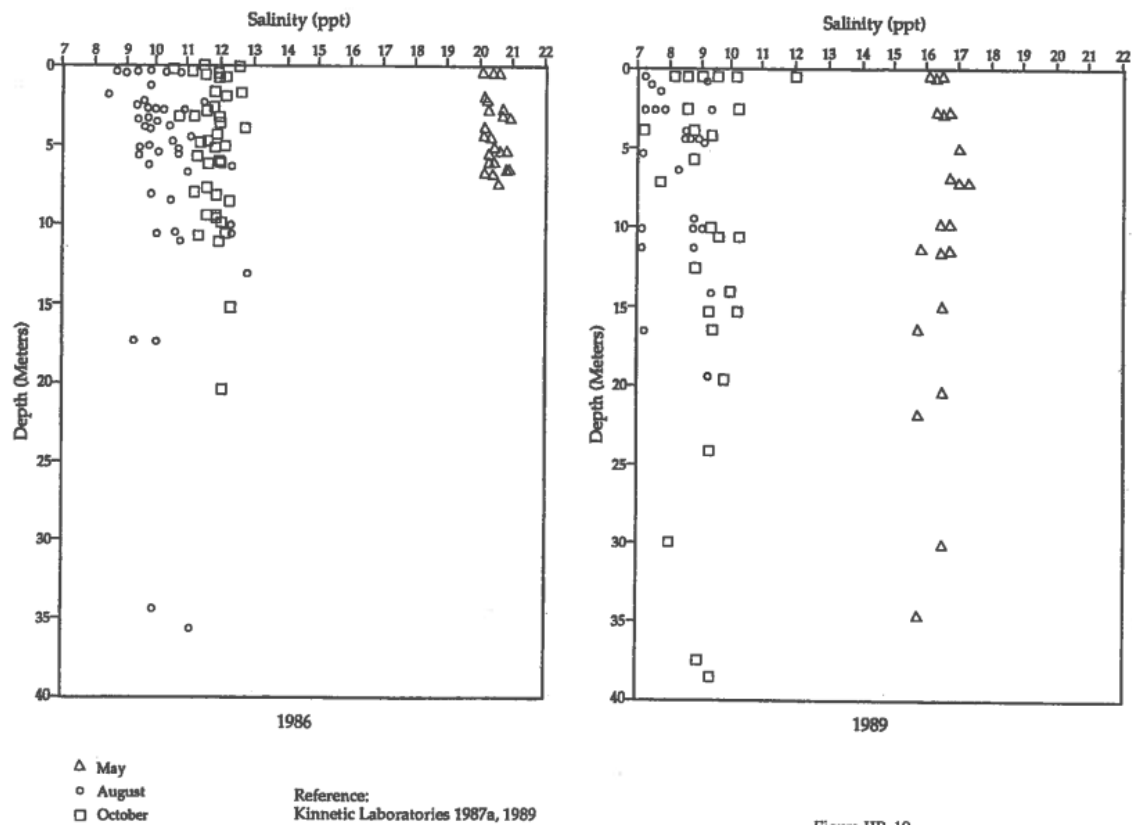


Figure 5. Water Column Profiles of Salinity Measurements near Point Woronzof in May, August, and October

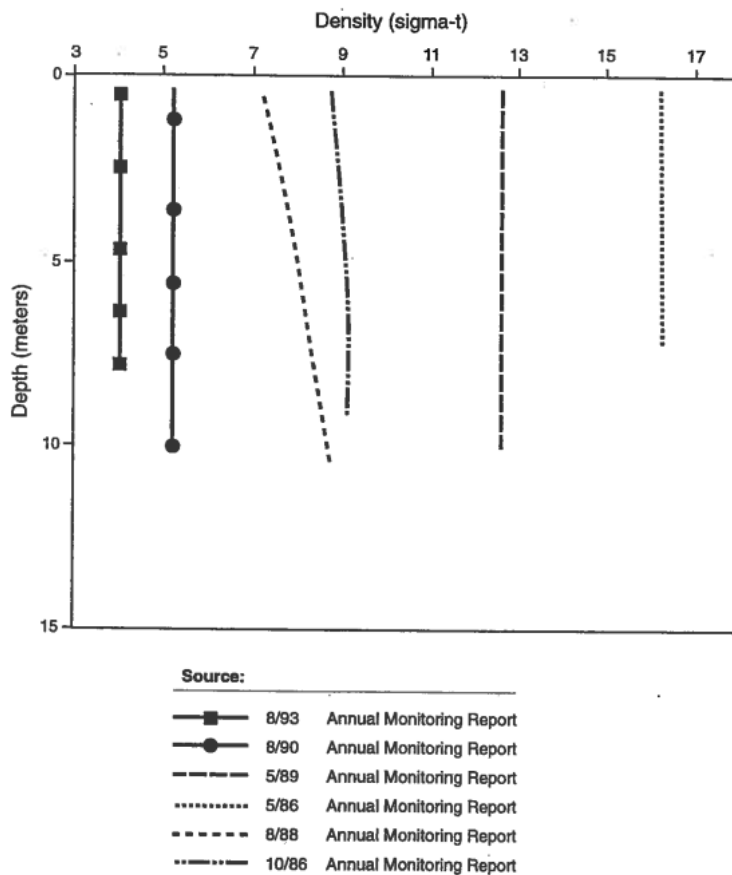


Figure 6. Examples of Seasonal Density Profile Variability in Knik Arm Based on AWWU Annual Monitoring Data

Dilution modeling developed for the AWWU 301(h) Waiver and NPDES Permit Application for the Asplund WPCF used hourly current measurements to evaluate discharges from the Point Woronzof outfall over a 24-hour time-series (refer to Table IIIA-3 in the 2005 AWWU 301(h) Waiver and NPDES Permit Application for the AWPCF). The dilution modeling results show that the lowest dilution predictions correspond to the lowest ambient current velocities. For example, dilution predictions range from 222 to 238 for highest tide elevations (+12 meters; +39 feet MLLW) with current velocities of 0.75 to 0.92 meters per second (2.5 to 3 feet per second), and dilution predictions range from 184 to 220 for lowest tide elevations (+3.5 to 4.8 meters; 11.5 to 15.7 feet MLLW), with current velocities of 0.2 to 1.0 meters per second (0.7 to 3.3 feet per second).

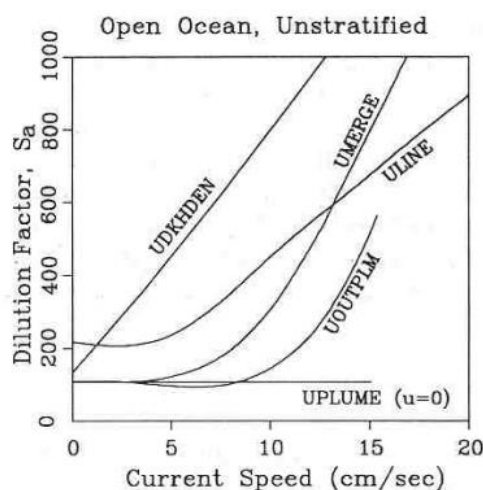
***The critical condition for the outfall mixing zone field tracer study of the Asplund WPCF outfall discharge to Cook Inlet is neap tidal conditions.*** The EPA's *Technical Support Document for Water Quality-based Toxics Controls* (EPA, 1991) states the following on page 75 in Section 4.4.3 - General Recommendations for Tracer Studies:

"The dye study recommended for obtaining a quick saltwater dilution assessment is one in which Rhodamine WT dye is administered to a discharge and monitored in the receiving waters for not less than 24 hours. The basic goal of this study is to determine the near-field nature of the effluent dilution, not the steady-state or far-field dilution. The environmental and discharge conditions selected for the study should be those that would elicit "worst-case" conditions (i.e., highest ambient concentrations in the receiving water). These include low wind, **neap tide** (tide of minimum range occurring during the 1st and 3rd quarters of the moon), plume trapping by density stratification, low rainfall and low riverine input, and, if possible, high effluent discharge." [Emphasis added]

The Asplund WPCF Outfall Mixing Zone dye tracer study is scheduled to occur under neap tide conditions and over two days to provide >20 hours of discharge dilution measurements.

In addition, EPA's publication *Dilution Models for Effluent Discharges* (EPA, 1994) states:

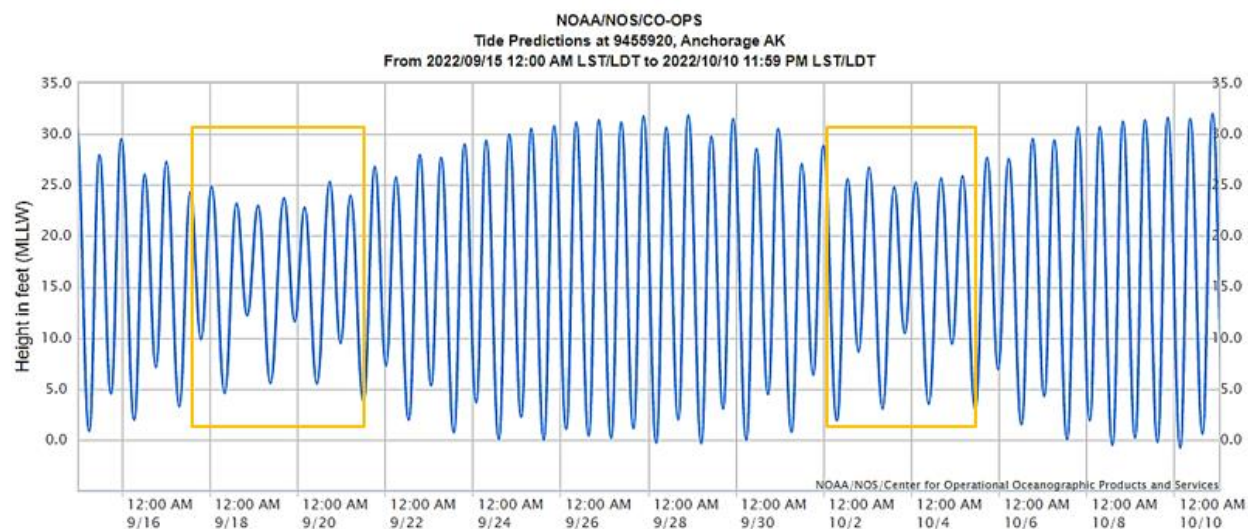
"Ambient currents will also influence the rate of dilution during the buoyant rise of the plume irrespective of jet momentum and buoyancy. As current speed increases so does initial dilution – based on Baumgartner et al. (1986). Refer to Figure 3 below (note model UPLUME does not include currents and gives constant dilution).



**Figure 3.** Dilution as a function of current speed.

In relation to permit requirements of regulatory agencies it is necessary to think of "allowable" initial dilution factors, or "critical" initial dilution factors based on conservative values of parameters in addition to current speed. "Critical" values in terms of EPA's 301(h) permit requirements (USEPA, 1982) include consideration of current direction as well as speed, and other environmental and wastewater factors. In the EPA regulations for a permit modified by section 301(h) of the Clean Water Act (USEPA, 1982), EPA allowed the lowest ten percentile current to be used in computation of the critical initial dilution value."

The range of tidal elevations and tidal-driven current velocities are greatest during spring tide periods and lowest during neap tide periods at Point Woronzof because the mass of water exchanged in Cook Inlet is greatest during spring tide periods. Figure 7 provides the tidal elevation predictions plotted for September 15 to October 10, 2022. The neap tide periods suitable for the outfall field tracer study are highlighted in boxes on the plot.



**Figure 7. Tide Elevation Prediction Plot for Point Woronzof Site with Neap Tide Periods Highlighted (Tides and Currents, 2022)**

To compare neap and spring tidal current velocities in the vicinity of Point Woronzof, plots of tidal current velocity predictions for the peak spring tide days and lower neap tide days have been developed based on the National Ocean Survey data predictions for Point Woronzof (based on the Port of Anchorage gage and Tides and Currents, 2022). Figure 8 provides a plot of tidal current predictions for the peak spring tide days of September 26-27, 2022. The flood tide currents predicted for these two days range from 168 to 184 centimeters per second (cm/sec) and ebb tide currents predicted for these two days range from 95 to 104 cm/sec.

In comparison, Figure 9 provides a plot of tidal current predictions for the neap tide days of October 1-2, 2022, when the AWPCF dye tracer study will be conducted at Point Woronzof. The flood tide currents predicted for these two days range from 112 to 161 centimeters per second (cm/sec) and ebb tide current predicted for these two days range from 63 to 99 cm/sec. These predicted neap tide current velocities for flood and ebb are approximately 20 to 25 percent lower than the predicted spring tide current velocities for flood and ebb.

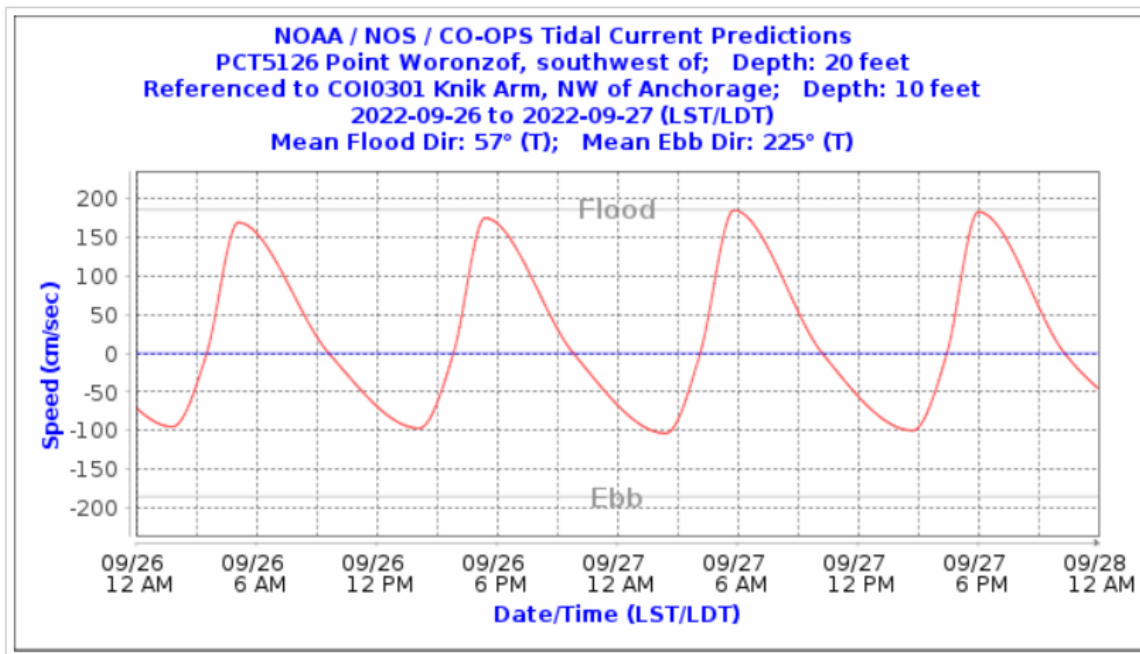


Figure 8. Predicted Tidal Current Velocities at Point Woronzof for Spring Tide Conditions (Tides and Currents, 2022)

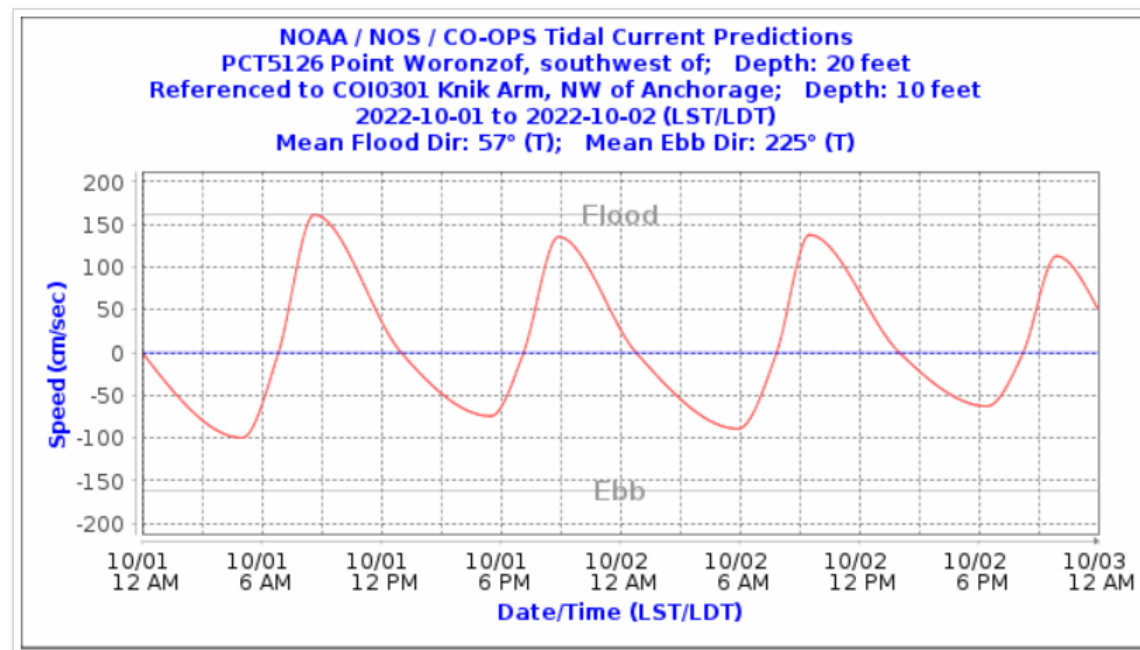


Figure 9. Predicted Tidal Current Velocities at Point Woronzof for Neap Tide Conditions (Tides and Currents, 2022)

### 1.3 Project Objectives

The objectives of this Outfall Mixing Zone Study of the AWPCF Outfall are to provide:

- site-specific field measurements at the outfall under low tidal exchange velocities in Cook Inlet to document the range of discharge dilutions, including minimal dilutions under low current speeds,
- field-measured ambient current data to analyze and develop statistics to apply as critical discharge conditions (as defined in EPA guidance) for use in dilution modeling,

- field-measured dilutions and ambient conditions to apply in dilution modeling to select, calibrate, and validate the most representative dilution model to use,
- dilution modeling results to represent the range of Cook Inlet and effluent discharge conditions, and
- a technical mixing zone study report that documents the ZID and CID for use in the 301(h) waiver and NPDES permit renewal, and that documents the field and modeling data and analyses.

To meet these project objectives, this project will be implemented by highly experienced outfall study personnel to: (1) develop accurate and defensible field measurements of the outfall diffusers performance, mixing zone regions, and ambient physical conditions for dilution modeling; and (2) document the selection and application of an appropriate dilution model to represent the outfall performance.

### Study Approach

The following project elements and stages define the study approach:

- Outfall Mixing Zone Study Plan – Prepare and submit a technical Outfall Mixing Zone Study Plan to be reviewed by AWWU, EPA, and the Alaska Department of Environmental Conservation (DEC) prior to conducting the dye tracer study.
- Field Study Planning – Coordinate planning for field study with AWWU personnel to ensure effective and efficient operations and adherence to health and safety protocols.
- Field Study – Perform site-specific field measurements and two days of dye tracer studies of the AWPCF Outfall (under neap tide conditions) in accordance with quality assurance/quality control (QA/QC) procedures defined in this Study Plan.
- Study Data Analyses – Take field measurements of dilutions and current measurements to summarize and document the outfall dilution performance under neap tide conditions.
- Dilution Modeling – Conduct dilution modeling analyses, applying dye tracer study conditions to select the most representative dilution model to apply.
- Model critical ambient current and stratification conditions to determine the CID and define the ZID boundary.
- Technical Report – Prepare a detailed technical outfall dilution performance study report for submittal to EPA and DEC. The report will document field methods, field-measured dilutions and currents, and dilution modeling methods and results. Report appendixes will include this Study Plan, outfall drawings, current measurements, bathymetry survey results of the Point Woronzof area, and dilution modeling input and output.

The Outfall Mixing Zone Study Report will document the field methods and results, dilution modeling methods and results, and recommend the ZID and CID for the AWPCF outfall. The report will also include appendixes with the Mixing Zone Study Plan, outfall drawings, current meter and bathymetry data for the outfall site, and dilution modeling input and output.

## 2. Field Study Methods

The field data collections and dye tracer studies of the AWPCF Outfall will be scheduled during a 1-week period in late September to early October 2022. Jacobs will provide all equipment and materials necessary for the field study, and a work vessel with differential global positioning system (DGPS) navigation will be used for work on Cook Inlet. Field equipment will be procured prior to the field study and transported to the AWPCF.

The Jacobs team will perform the dye tracer study of Outfall 001 during neap tide conditions. The field study will include collecting site-specific physical measurements of current velocities and directions and water column density profiles, and field-measured dilutions using Rhodamine WT injected into the effluent and then measured after discharge from the diffuser during ebb and flood tidal conditions on two consecutive days. The dye will be injected into the AWPCF effluent and allowed to mix completely, after which the initial dye concentration will be measured in the effluent prior to discharge from the outfall. The receiving water measurements of tracer (dye) will be recorded, and DGPS survey grade recordings will log the sampling locations in Cook Inlet.

Figures 3 illustrates the work sites for dye injection and initial dye measurements and potential RTK survey base sites at the AWPCF and along the outfall route on land.

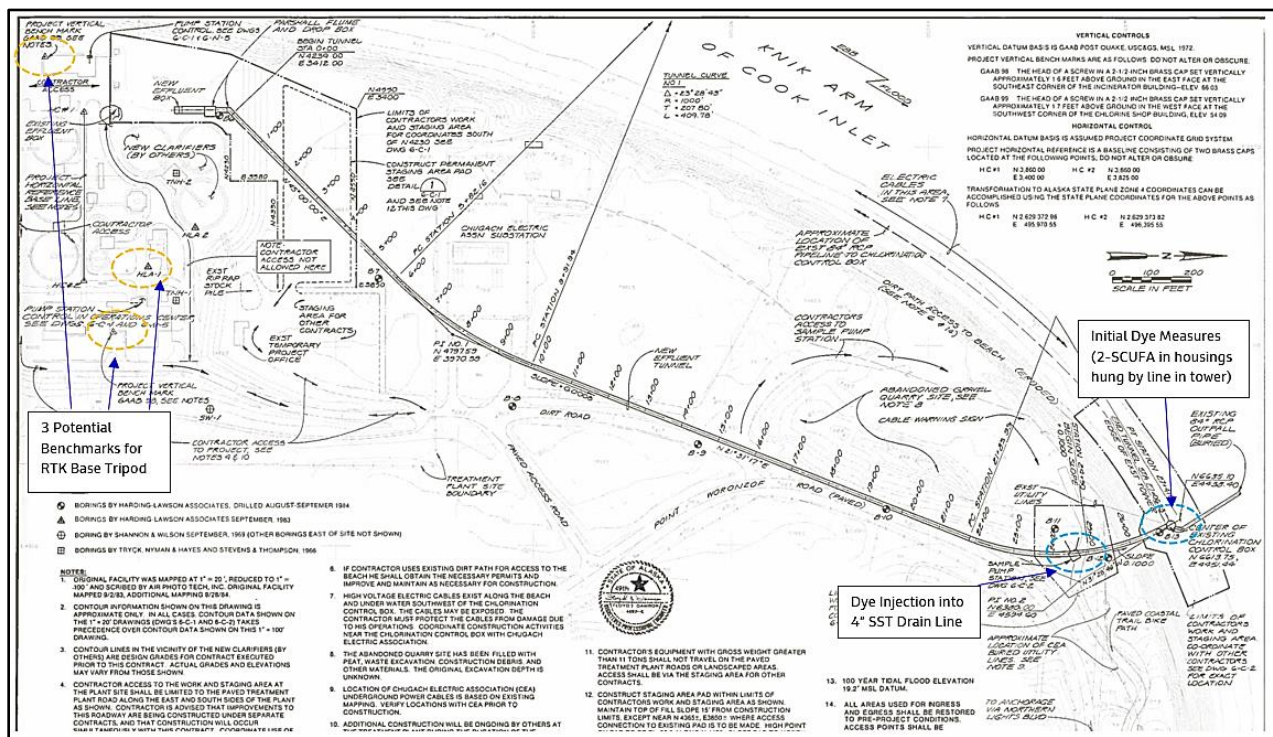
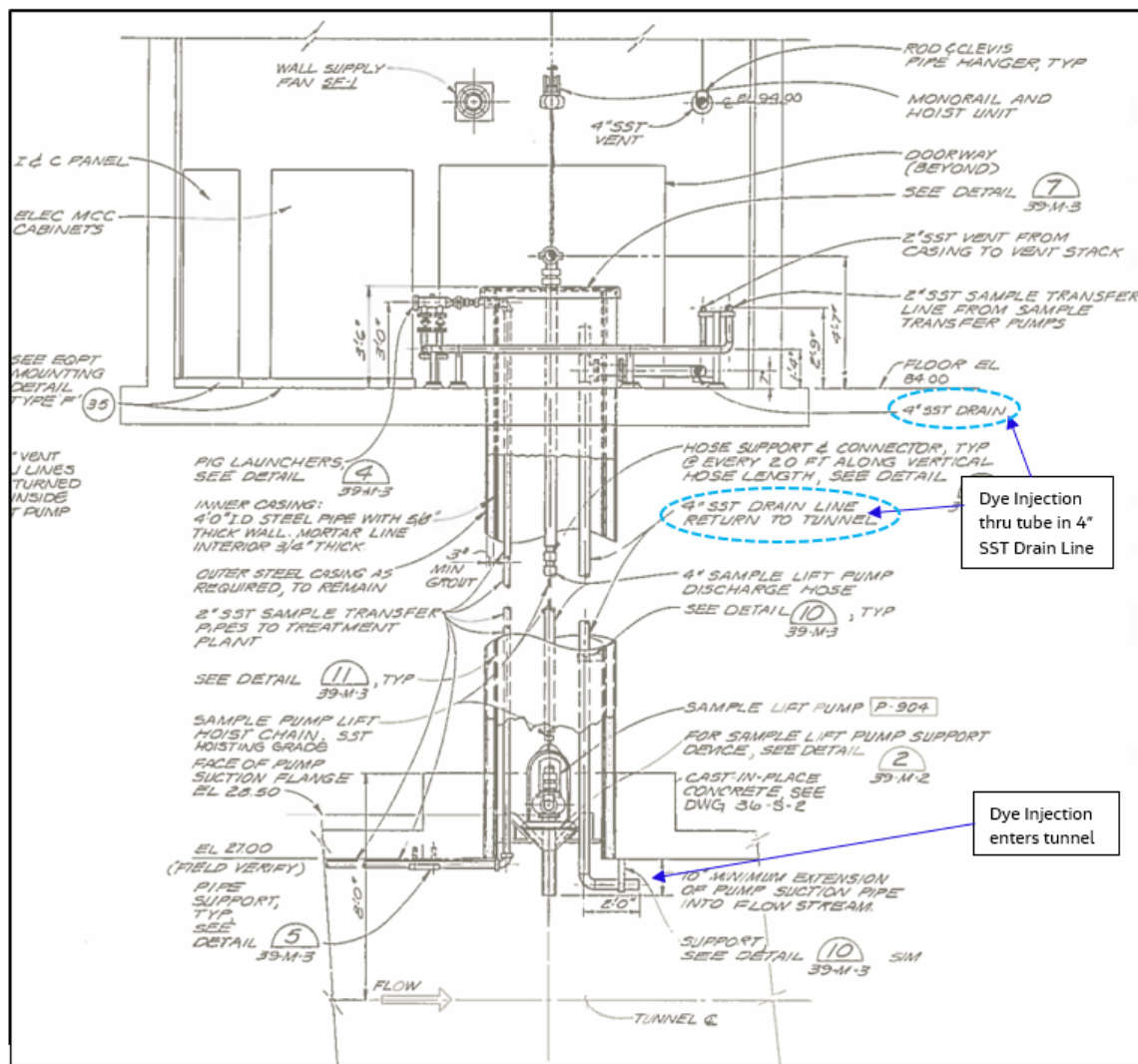


Figure 3. Plan View Drawing of AWPCF Outfall Showing Locations of the Potential Survey Benchmarks at the AWPCF, the Planned Dye Injection Site at the Outfall Tunnel Sample Pump Station, and the Initial Dye Measurements Site at the Outfall Chlorination Tower

The dye will be injected into the AWPCF outfall tunnel via the 4-inch drain line located at the sample pump station at a flow-paced rate designed to keep the initial concentrations as constant as possible. Dye will be injected at a calibrated and flow-paced rate to achieve a target dye injection concentration of approximately 800 ppb for the range of effluent flows that occur between 0800 and 1900 on the tracer field study days. Figure 4 shows a drawing of the sample pump station where the dye injection is planned.



**Figure 4. Drawing of the Outfall Tunnel Sample Pump Station and Planned Dye Injection into 4-inch Drain Line**

Initial dye measurements will be recorded by a Self-Contained Underwater Fluorescence Apparatus (SCUFA) that will be installed in the effluent flow downstream from the injection site. Two SCUFA's will be installed on a cable suspended in the effluent flow rising inside the chlorination tower on the inshore side of the weir to independently determine the dye concentrations in the effluent prior to discharge via the outfall into Cook Inlet. The dye injection and measurement period shall be approximately 10 hours in duration during each of the two field tracer study days. Sampling on Cook Inlet will be limited to daylight hours (for safety). Figure 5 shows the chlorination tower on the shoreline where the SCUFA's will be installed.

The approximate 10-hour dye measurement period will capture ebb and flood tidal conditions on Cook Inlet on each of the study days. For safety reasons, the duration of field dye measurements on Cook Inlet will be limited to daylight hours. These measurements will include the following elements:

- Vertical profile measurements and horizontal drifting transects of dye tracer concentrations with depth at distances from the outfall (including at the ZID boundary) in the path of the discharge plume—during ebb and flood tidal conditions during the study,
- Measurements of conductivity and temperature at the same locations as dye measurements, as well as background measurements,

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- Current speed and direction measurements near the outfall during the field study to document plume travel velocities and to apply in dilution modeling,
- Sampling position coordinates to be determined using DGPS, and
- Calibration of equipment before and, in the case of fluorometers, after field data collections.

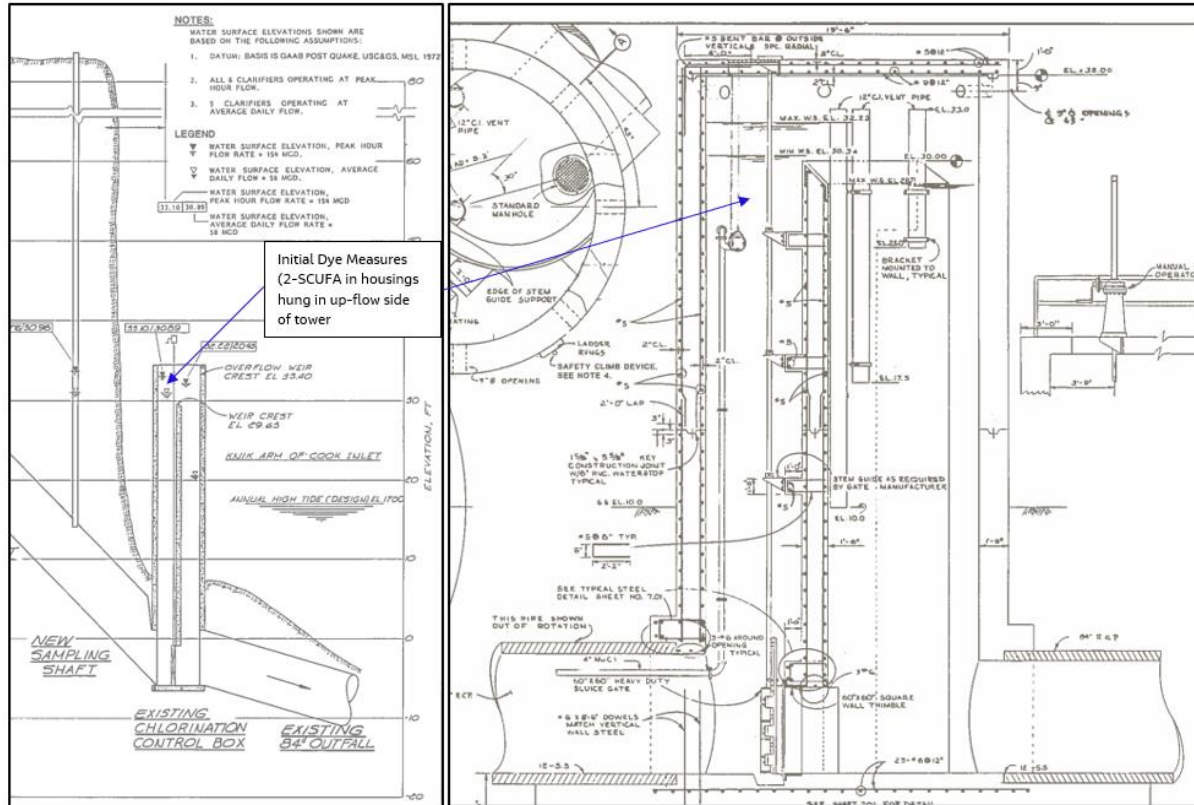


Figure 5. Sectional Drawings of the Outfall Chlorination Tower and the Initial Dye Measurements Site

### 2.1 Field Study Activities

Field study activities with stages and timelines are listed below:

- **Prior to Field Study** – Approximately 1 month prior to the field study, Jacobs field lead and AWWU personnel will conduct a pre-study coordination meeting at the AWPCF to review field study plans for dye tracer injection and initial measurements, work site access, safety, and security procedures, and confirm procedures for the tracer study.
- **Field Study Day 1** – The Jacobs team will mobilize to the AWPCF, hold a coordination meeting with AWWU personnel to confirm site access, safety, and security procedures, perform effluent and receiving water collections for dye standards preparation, and unload equipment.
- **Field Study Day 2** – The Jacobs team will complete dye standards preparations, set up the dye injection equipment, conduct instrument calibrations, prepare field equipment, and test the dye study instruments.
- **Field Study Day 3** – The Jacobs team will complete dye injection equipment setup and testing, install the SCUFA into the chlorination Tower, complete instrument calibrations, and complete final field equipment preparations.

- **Field Study Day 4** – The Jacobs team will initiate metered dye injection into the effluent at the outfall tunnel sample pump station structure and conduct dye tracer measurements of the Outfall 001 discharge in Cook Inlet during daylight hours. The dye tracer study will involve water column measurements of dye, temperature, and conductivity from a work vessel on Cook Inlet. Dye tracer concentrations will be recorded during ebb and flood tidal conditions at water column profile sites and on drifting transects in the discharge plume. Vessel launching at the Port of Anchorage will occur at approximately 0900 to allow sufficient water depth at the boat launch. Dye tracer measurements are planned between approximately 0930 and 1900 hours. A DGPS navigation system will be used to record vessel position to provide accurate tracking of the location of dye measurements. Vessel retrieval at the Port of Anchorage will occur at approximately 2000 hours to allow sufficient water depth at the boat launch.
- **Field Study Day 5** – The Jacobs team will initiate metered dye injection into the effluent at the outfall tunnel sample pump station structure and conduct dye tracer measurements of the Outfall 001 discharge in Cook Inlet during daylight hours. The dye tracer study will involve water column measurements of dye, temperature, and conductivity from a work vessel on Cook Inlet. Dye tracer concentrations will be recorded during ebb and flood tidal conditions at water column profile sites and on drifting transects in the discharge plume. Vessel launching at the Port of Anchorage will occur at approximately 0945 to allow sufficient water depth at the boat launch. Dye tracer measurements are planned between approximately 1030 and 1900 hours. A DGPS navigation system will be used to record vessel position to provide accurate tracking of the location of dye measurements. Vessel retrieval at the Port of Anchorage will occur at approximately 2045 hours to allow sufficient water depth at the boat launch.
- **Field Study Day 6** – The Jacobs team will conduct post-study instrument calibrations, remove dye injection equipment, retrieve the initial dye measurement instruments from the chlorination tower, and clean up instruments and equipment at the AWPCF.
- **Field Study Day 7** – The Jacobs team will pack equipment at the AWPCF, demobilize from the AWPCF site, and ship the equipment.

## 2.2 Field Instruments and Materials

The specific details of the instruments, equipment, and materials to be provided by Jacobs for use in the field study are listed below:

- Two SeaBird SBE-19 conductivity, temperature, and depth (CTD) instruments. These instruments will be deployed from the vessel to record vertical water column profiles and drifting transects during the field tracer study period. The SeaBird instruments will be fitted with Turner Designs SCUFA fluorometer instruments that may be used as a secondary method to record dye tracer measurements. The SeaBird SBE-19 CTDs are factory calibrated instruments; the SCUFA (or equivalent) instruments will be calibrated in the AWPCF laboratory before and after the field tracer studies.
- Two Turner Model 10-AU fluorometers will be set up for flow-through operation and used as the primary instruments to measure receiving water dye concentrations in the receiving water tracer study.
- Two Turner Designs SCUFA fluorometers will be used to measure initial dye concentrations after dye injection at the plant (primary plus backup instrument).

- Masterflex (or equivalent) peristaltic dye injection pumps (three units) will be used for calibrated dye injection into the plant effluent.
- Masterflex (or equivalent) large peristaltic pumps (two units) will be used to pump receiving water through a submerged intake hose attached to the SBE-19 CTD instrument into a Turner Model 10-AU fluorometer during the field tracer study.
- Rhodamine WT dye (up to 20 gallons) will be used during a maximum 10-hour injection period for each outfall tracer study day to achieve a target of 800 parts per billion (ppb) dye concentration in the discharge effluent.
- Two RDI Acoustic Doppler Current Meters will be deployed near the AWPCF outfall terminus prior to the field tracer study to measure current speed and direction during a two-week period. Current measurements will be recorded every 6 minutes during deployment to coincide with water elevation recordings by the National Oceanic and Atmospheric Administration (NOAA) tidal gage at the Port of Anchorage.
- One 26-foot work vessel with DGPS navigation.
- Field laptop computers (three) for data logging and calibrations.

Table 2 provides a listing of the field instruments for the dilution study, including primary and backup units.

**Table 2. Field Equipment and Instrumentation for the Outfalls Mixing Zone Study**

Equipment Item	Purpose	Number of Units	Accuracy Standard
SeaBird Electronics SBE-19 Plus V2 CTD	Measurement of ambient conductivity, temperature, and depth	2	Conductivity: $\pm 0.001$ S/m Temperature: $\pm 0.01^{\circ}\text{C}$ Depth: $\pm 0.05$ m
Turner Designs SCUFA submersible fluorometer	Measurement of fluorescent dye concentration in the receiving water	4	Minimum dye detection to 0.20 ppb*
Turner Designs 10-AU field fluorometer	Measurement of fluorescent dye concentration in effluent or receiving water (SCUFA backup instrument)	2	Minimum dye detection to 0.5 ppb*
RDI acoustic Doppler current profiler	Measurement of <i>in-situ</i> current velocity (speed and direction)	2	Speed: $\pm 0.5$ cm/sec Direction: $\pm 0.5$ degrees
Trimble GNSS differential GPS	Vessel positioning and precision navigation	2	$\pm 0.2$ m
MasterFlex peristaltic pump	Dye injection into plant effluent at a constant flow rate	2	0.2 mL/min
Positive displacement and/or peristaltic pump	Pump receiving water through the 10-AU fluorometer, if needed	3	1 mL/min (minimum delivery rate of 3 L/min)

\*An accuracy of 0.5 ppb is conservatively assumed for calculation purposes; actual instrument accuracy is 0.05 ppb.

$^{\circ}\text{C}$  = degrees Celsius; cm/sec = centimeters per second; L/min = liters per minute; m = meter; mL/min = milliliters per minute; ppb = parts per billion.

## 2.3 Quality Assurance/Quality Control

The QA/QC objective for the field study is to collect measurements of wastewater dilution and receiving water conditions that are of known and acceptable quality. The following requirements will be met to achieve these objectives:

- Provide verifiable dye injection rates and initial dye concentrations.
- Provide verifiable equipment calibration with pre- and post-study calibrations of the fluorometer instruments.
- Provide verifiable laboratory quality control and quality assurance documentation.
- Maintain accurate positioning for measurements.
- Provide equipment redundancy (backup equipment).
- Examine dye injection site and downstream sample collection site to verify proper mixing before initial dilution samples are taken.

This study plan has been developed as the basic element of quality assurance and control activities for the field study. A field operations plan will also be developed and discussed with AWWU and AWPCF personnel prior to the field study to define the detailed study schedule, communications, personnel assignments, and field safety and security procedures. Project-specific field safety instructions will be prepared by the field study team and reviewed by the project Health, Safety & Environment coordinator.

## 2.4 Equipment Calibration

All equipment will be obtained prior to the beginning of the dye study. Each instrument will be checked upon its arrival to confirm that it is in working condition. Each instrument will also be calibrated immediately prior to the beginning of the dye study and, when appropriate, following the study. Calibration methods for each instrument are described below:

- **Current Meters** – These instruments are calibrated by the manufacturer. Calibration results will be used during data reduction and the calibration history will be incorporated in the Mixing Zone Study Report for the units used in the study.
- **CTD instruments** – Conductivity, temperature, and depth instruments are factory calibrated; the current calibration certificates will be confirmed before conducting the dye studies. Calibration results will be used during data reduction and calculation of the water column density structure. Calibration history will be incorporated in the Mixing Zone Study Report for the units used.
- **Dye Pumps** – The dye pumps will be calibrated at the locations where they will be used during the dye study. The pumps will be equipped with a micrometer control to accurately determine pumping rate. The flow rate scale will be calibrated with the dye at ambient temperature by repeatedly discharging dye into a graduated cylinder for a fixed period of time at various flow rate scale settings. According to the manufacturer, a reproducible metering accuracy of greater than one percent can be expected when handling medium-viscosity fluids if fluid differential pressure, fluid viscosity, and electric line voltage remain constant. To verify that none of these factors affects expected dye flow rates during dye injection, dye flow rates will be verified and logged prior to the start of dye injection and adjusted at one-half hour intervals based on effluent flows during the field study.

- **Fluorometers** – Turner Designs SCUFA and 10-AU field fluorometers will be calibrated according to the manufacturer's specifications such that they measure total dye concentration in the appropriate range for their use. Measurements in the receiving water will have a range of 1 to 100 ppb; effluent initial dye measurements will have a range of 500 to 1,500 ppb. Two types of dye standards will be prepared with the dye used in the study. One set of standards will be prepared using effluent from the plant for calibrating initial dye measurement instruments. A second set of standards will be prepared using background Cook Inlet water for calibrating receiving water dye measurement instruments. Background Cook Inlet water will be collected from the Port of Anchorage dock prior to the dye study and used to prepare dye standards for calibrating receiving water dye measurement instruments. Immediately following the dye study, a second set of fluorometer calibration measurements will be recorded using effluent and receiving water dye standards, as well as effluent and background Cook Inlet water. The second set of calibration measurements will be compared to the pre-study calibration data after correction for temperature. The pre-and post-study calibration curves will be used to correct or adjust the observed dye concentration and dilution and the results will be documented in the Mixing Zone Study Report.

## 2.5 Data Analysis and Environmental Mapping

The extensive set of field measurements recorded during the field study will be compiled and processed. Data sets to be analyzed include the ambient current meter records, dye tracer study measurements in the water column, DGPS vessel and instrument position records, and the effluent initial dye concentration, flow, and temperature records.

The dye tracer study data will be analyzed and summarized into tabular and graphical formats to represent the field-measured tracer plume at distances from the AWPCF outfall under ebb and flood tides. These dye tracer study data will be used in the selection of dilution models and validation of the dilution modeling and presented in the study report. In addition, field tracer measurements recorded during the tracer study may be used to represent plume overlap due to tidal-induced flow reversal. Effective plume dilutions will be calculated if overlapping plume measurements are recorded during the field tracer studies. Plume reversal (reflux) measurements will be summarized and analyzed to determine whether any measurable plume overlap reduces effective dilution within time scales that are relevant to acute and chronic water quality criteria and drifting organism exposure in the mixing zone.

Effluent flow and temperature data collected during each tracer study will be compiled for use in modeling to compare to the field-measured dilutions. The ambient current data collected will be compiled and analyzed to define ambient current velocities at the outfall during the field studies for the specific tidal conditions; these data will be employed in the modeling to compare to field-measured dilutions. Dye tracer study field-measured dilutions will be used in dilution modeling to compare to dilution modeling results for different models to allow for selection of the best model to represent the field-measured dilutions at distances from the outfall for the field study conditions.

Physical characteristics and uses of the Point Woronzof area will be developed on a map. The information will include the following elements within approximately one-half mile radius of Point Woronzof:

- creeks and other NPDES discharges – based on DEC database and mapping,
- public parks and public uses within a one-mile radius of AWPCF outfall, and
- detailed bathymetry and bedform sediment in the vicinity of Point Woronzof.

### 3. Dilution Modeling

#### 3.1 Modeling Objective and Approach

Modeling will be used to predict wastewater dilutions based on the field performance study results and receiving water conditions. The field-measured dilutions will be used for direct comparisons to dilution model results using Visual Plumes (VP) and CORMIX models. The basis for model selection will be documented in the study report. Measured receiving water and effluent conditions will be used as inputs to dilution modeling for model selection and validating the model predictions.

Dilution modeling analyses will first focus on the dye tracer study conditions. Field-measured dilutions for the AWPCF outfall will be used to compare and select the dilution model (UM3 or DKHW or CORMIX2) for application over the range of discharge conditions. Field-measured and model-predicted dilutions will be compared during the model selection process. The selected dilution model will be validated and calibrated with these measurements and the results will be documented in the Mixing Zone Study Report. Dilution modeling will be conducted using the collected ambient current data, water column density data, and AWPCF effluent data (i.e., continuous flows and temperature data) for the field dye study days.

#### 3.2 Model Selection

Based on evaluations of available dilution models, the following will be considered for use in modeling the AWPCF outfall: (1) VP, a model interface and file manager that includes both plume models DKHW and UM3 (Frick et al., 2000) and (2) CORMIX (Doneker and Jirka, 2007). The dilution model selection and approach will be developed through screening model runs and reviews with a senior reviewer and modeler. One of these mathematical models will be applied—depending upon which is shown to best represent the diffuser dilutions measured during the field study—to simulate dilution and plume behavior (plume rise and dimensions) under a range of conditions. It is possible that the image solution modeling approach using DKHW could be required to match the field-measured dilutions, as it was shown to provide the best match in the 1988 modeling.

Each of these modeling systems and models is discussed in more detail in the following sections.

##### 3.2.1 Visual Plumes

VP is an update of the PLUMES modeling system developed by the Environmental Research Division of the U.S. Environmental Protection Agency (Baumgartner et al., 1994). VP is a Windows-based computer application that supersedes the DOS PLUMES mixing zone modeling system (Baumgartner et al., 1994). VP simulates single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. VP supports several dilution models, including the DKHW model based on UDKHDEN (Muellenhoff et al., 1985), the surface discharge model PDS (Shirazi and Davis, 1974), the three-dimensional UM3 model based on UMERGE, and the NRFIELD model based on RSB (Roberts, Snyder, and Baumgartner; 1989a, 1989b, 1989c). The Brooks equations (Brooks, 1960) are included in VP for predicting subsequent dilution and plume behavior in the farfield.

The time-series, file-linking capability of VP provides a way to simulate outfall performance over longer periods of time. Most effluent and ambient variables can be input from files that store data that change over time (i.e., non-steady state processes). This is the heart of its pollutant build-up capability, which is designed for one-dimensional tidal estuaries to estimate

background pollution from the source in question. The timeseries file linking capability of VP is supported by summary graphics (i.e., those which focus on overall performance indicators, like mixing zone dilutions or concentrations).

The following briefly describes the capabilities of the models within the VP model interface that will be considered for use in the mixing zone dilution study.

#### **3.2.1.1 DKHW**

DKHW is a three-dimensional mathematical model that considers variable ambient receiving water current and density profiles with depth (Muellenhoff et al., 1985). The model uses a fourth-order integration routine along the centerline of the effluent plume to trace its position and average dilution over time (i.e., Eulerian fluid mechanics). The model calculates the average dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single diffuser or single row of multiple diffuser ports in either stagnant or flowing environments. DKHW is sensitive to water column density gradients and ambient velocities. Comparisons of field and dilution modeling results show that jet-integral plumes models such as DKHW provide relatively conservative dilution estimates (i.e., predict lower dilutions than actually achieved).

The output of each DKHW model case provides sequential calculation of both dilution and plume distance from the discharge port until initial dilution is completed; this output can be used to summarize the dilutions and plume depth at distances from the outfall discharge. In Visual Plumes, DKHW is integrated with a farfield dilution model. The Brooks method is used to develop farfield dilution predictions, typically at the mixing zone boundary. These equations are incorporated into VP for predicting farfield plume behavior and dilution.

#### **3.2.1.2 UM3**

UM3 is a three-dimensional mathematical model that calculates the flux-averaged dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single diffuser port or from single row of multiple diffuser ports in either stagnant or flowing environments. The UM3 model analyzes effluent discharges by tracing the position of the plume through its trajectory path (i.e., Lagrangian fluid mechanics). The model approximates plume development by using single, one-step integrations over discrete time increments.

The output of each UM3 model run provides sequential calculation of both dilution and plume distance from the port(s) until initial dilution is complete. Model outputs can be used to predict the dilutions and plume depth at the completion of initial dilution and at various distances downstream of the discharge. As previously stated, the VP interface contains farfield dilution algorithms based on equations developed by Brooks.

#### **3.2.2 CORMIX**

The CORMIX modeling system, developed for the U.S. Environmental Protection Agency at Cornell University, is a rule-based expert system that classifies the interaction of discharges and the receiving water (Doneker and Jirka, 2007). The program makes many of the decisions for the model user based on the input parameters that are provided. The system was designed for the non-specialist model user so that plume predictions could be made without necessarily having prior knowledge of mixing processes and dilution modeling. The CORMIX models use empirically derived curve-fit equations to make dilution predictions. These equations are selected from length scales that are determined from parameters input by the user.

CORMIX 2, which is designed to simulate submerged, multi-port line diffusers, is the module that will be considered for application in this study. The developers of CORMIX also incorporated a three-dimensional jet integral model (CORJET) for near-field dilution predictions. This jet integral model is very similar to DKHW in VP and provides similar near-field prediction results; however, CORJET is accessible only when CORMIX has determined that the discharge conditions are hydrodynamically “stable.” Typically, CORMIX 2 simplifies near-field mixing processes by representing the multi-port diffusers as an equivalent slot (line source) of momentum and buoyancy. This simplification occurs when CORMIX predicts that an unstable discharge exists; under these conditions, mixing is based on the plume characteristics *after* plumes from adjacent diffuser ports have merged.

### 3.3 Modeling Conditions and Assumptions

Once the representative dilution model is selected to represent AWPCF outfall dilutions, dilution model inputs will be developed for tidal conditions defined in the Technical Support Document for Water Quality-based Toxics Control (EPA, 1991) and effluent flows (and temperatures) consistent with the Amended Section 301(h) Technical Support Document (EPA, 1994). Model inputs will include effluent flows and temperatures, outfall port depths at Mean Lower Low Water and Mean Sea Level, ambient density profiles for tidal and seasonal conditions, and ebb and flood tide current velocities based on field-measured currents. Ambient current velocities to apply in modeling include 10<sup>th</sup> and 90<sup>th</sup> percentile currents under ebb and flood conditions (to align with acute water quality criteria conditions) and 50<sup>th</sup> percentile currents under ebb and flood conditions (to align with chronic water quality criteria conditions).

Model inputs of effluent flow and temperature data will be based on three years of AWPCF records. The highest 3-hour average flow, maximum day (dry and wet seasons), maximum month average, and annual average effluent flows will be calculated to apply in modeling. Effluent flow trends will be evaluated to determine whether projected effluent flows for 2030 would be more than 5% above existing flows and would need to be used in dilution modeling. Dilution modeling results will be summarized into tabular and graphical forms, and model input and output will be included in the report appendix.

A summary of the preliminary model input parameters that will be used to develop the discharge scenarios are as follows:

- **Ambient current speed:** This will be based on 10<sup>th</sup>, 50<sup>th</sup>, and 90<sup>th</sup> percentile current speeds measured near the outfall under neap and spring tides.
- **Water (discharge) depth:** Outfall port discharge depths applied in the dilution modeling will include increments of the range of measured tidal elevations at Point Woronzof (as measured by the Port of Anchorage NOAA gage), and will include the lowest 10<sup>th</sup> percentile, 50<sup>th</sup> percentile (mean tide level), and 90<sup>th</sup> percentile depths over the range of tidal elevations at Point Woronzof.
- **Ambient water column density profiles:** These will be based on summer and winter water column density conditions from the field study and oceanographic measurements made by others in upper Cook Inlet.
- **Number of diffuser ports:** Outfall 001—3 ports will be assumed.
- **Port diameter:** Outfall 001—23 inch will be used.
- **Port spacing:** Outfall 001—4 feet on center around outfall turret will be used.

- **Port discharge angles:** Outfall 001—3 ports each oriented 45 degrees from adjacent ports and center port oriented orthogonal to tidal exchange axis and 0 degrees (horizontal) vertical orientation above the bed.
- **Port elevation (height above bottom):** This will be confirmed from outfall drawings.
- **Effluent flow rates:** Existing AWPCF flows (2019–2022), and projected 2030 flows (dry and wet season)—the highest 3-hour average flow, maximum day (dry and wet seasons), maximum month average, and annual average effluent flows will be calculated to apply in modeling – in accordance with the EPA's *Amended Section 301(h) Technical Support Document* (EPA, 1994).
- **Effluent temperature:** This will be calculated from AWPCF effluent monitoring records.

The results of the dilution modeling will include: (1) a comparison of model-predicted versus field-measured dilution for the field study; (2) predicted dilutions, plume dimensions (width and depth), and temperatures at the ZID for the range of critical discharge conditions; and (3) predicted effective dilutions during tidal-induced flow reversals. Dilution modeling results will be summarized into tabular and graphical formats. Model input and output will be included in an appendix of the Mixing Zone Study Report.

### 3.4 Technical Study Report

A technical study report will be prepared summarizing the mixing zone study of AWPCF Outfall 001, including field measurements of the discharge site, outfall tracer study data, effluent and receiving water data used in modeling, and detailed modeling results. Graphical plots of the field sampling sites around the AWPCF outfall will be included in the report. Model input and output, field measurements, and other supporting information will also be provided.

An environmental mapping section will be included in the report. These maps and supporting documentation will include information on the following elements within a one-half mile radius of the AWPCF Outfall 001:

- creeks and other NPDES discharges (based on DEC database and mapping),
- public parks and public uses within one-half mile radius of AWPCF outfall, and
- bathymetry and bedform in the vicinity of Point Woronzof based on the detailed bathymetric survey performed under Task 10, which will provide bathymetry and habitat mapping of the seabed near the discharge site.

A draft Outfall Mixing Zone Study Report will be developed, reviewed by AWWU, comments incorporated as appropriate, and submitted to EPA and ADEC. A meeting will be planned to discuss the results of the study and their application in the 301(h) and NPDES permit renewal with AWWU, EPA, NMFS, and ADEC.

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